PREFERENCE FOR LESS FREQUENT SHOCK UNDER FIXED-INTERVAL SCHEDULES OF ELECTRIC-SHOCK PRESENTATION

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Lever pressing by 2 squirrel monkeys was maintained under fixed-interval 6-min and fixed-interval 2-min schedules of electric-shock presentation. Preference for these schedules was assessed during three experimental phases. In all phases, responses on one lever produced shock according to one or the other fixed-interval schedule, and responses on a second, changeover, lever switched between schedules. The opportunity to change over was presented during separate choice periods (during which the fixed-interval schedules did not operate) that followed the first through fourth shocks in each schedule. If no changeover occurred during those choice periods, a changeover automatically occurred following the fifth shock. In Phase I, durations of the choice periods were fixed. In Phase II, the choice periods equaled a proportion of their respective fixed interval. During Phase III (completed with 1 monkey) a response on the changeover lever during a given choice period reinstated the most recent fixed interval, and a failure to respond resulted in a changeover. During each of these phases, distinct preferences developed for the 6-min schedule. These results suggest that the maintenance of lever pressing by fixed-interval presentation of electric shock may not be an example of positive reinforcement, and that the response-maintaining characteristics of shock presentation may derive from other properties of the schedule.

Key words: shock-maintained behavior, choice, preference, aversive control, fixed-interval schedules, lever press, squirrel monkeys

Under most experimental conditions, noxious electric shock functions as an aversive stimulus—responding that produces shock is suppressed, or punished, and responding that terminates or postpones shock is maintained, or negatively reinforced (see Azrin & Holz, 1966; Hineline, 1977). A particular group of

experiments, however, has yielded results that seem to conflict with this traditional formulation. In these experiments, squirrel monkeys' lever pressing has been maintained indefinitely under conditions in which electric shock is intermittently presented as the sole consequence of responding (shock-maintained behavior).

Many studies of shock-maintained behavior have reported behavioral effects that resemble those ordinarily obtained under comparable conditions of food or water presentation. For example, temporal patterns of responding maintained under fixed-interval (FI) and variable-interval (VI) schedules of shock presentation are typical of those observed when food is similarly presented, and functional relations between response rate and parameters of shock under these schedules are similar to those obtained with food (see Morse & Kelleher, 1977, for a review). Additionally, rates and patterns of responding maintained by chained and second-order schedules of shock presentation are characteristic of those usually produced under comparable food schedules (Byrd, 1972; Gardner & Malagodi, 1981; Malagodi, Gardner, Ward, & Magyar, 1981), and higher response rates are maintained under response-dependent than under response-independent sched-

ules of shock presentation (McKearney, 1974; Malagodi, Gardner, & Palermo, 1978).

On the other hand, clear differences exist between food- and shock-maintained behavior. Responding eventually ceases following a transition from an FI schedule of shock presentation to a yoked fixed-ratio (FR) schedule (Branch & Dworkin, 1981), and presentation of shock according to an interresponse-time (IRT) > *t* schedule decreases the frequency of long IRTs rather than increasing them (Galbicka & Branch, 1981). In other areas, equivocal results are obtained. For example, administration of some drugs produce similar effects on comparable rates and patterns of behavior maintained by food and shock presentation, whereas others affect food- and shock-maintained behavior differently (see Galbicka, 1990, for a review).

Attempts to clarify the nature of the behavioral processes involved in shock-maintained behavior vary. One conceptualization views schedules as fundamental determinants of behavior (Morse & Kelleher, 1970, 1977). This view challenges traditional treatments of both positively reinforcing and aversive stimuli as possessing inherent and immutable properties, and instead suggests that the experimental history, the ongoing pattern of responding, and the schedule of presentation interact to determine the consequent stimulus function of an event. Thus, under some arrangements, presentation of a stimulus will maintain responding (positive reinforcement), whereas under others presentation of the same stimulus will suppress responding (punishment).

Other approaches attempt to account for shock-maintained behavior within the context of traditional formulations. For example, one view suggests that shock-maintained behavior is the product of molecular aversive control in which relatively long IRTs are punished (Galbicka & Platt, 1984); another suggests that shock-maintained behavior may result from elicitation or induction by periodic shock presentation (e.g., Hutchinson, 1977; Hutchinson, Renfrew, & Young, 1971).

Although different along many dimensions, these accounts all rely upon data from single-operant procedures, in which response rates, temporal patterning, or IRT distributions are used as supportive evidence. The present experiments followed the suggestions made by Findley (1962), Herrnstein (1970), and others, that multioperant procedures may have advantages over single-operant procedures in assessing the putative reinforcing or punishing properties of stimuli. Concurrent, or choice, procedures have been successfully used in a variety of contexts to quantify the relative reinforcing or punishing efficacy of conditions associated with various behavioral alternatives. When responding is maintained by food or water presentation, preference, measured by a higher relative response rate, usually tracks relative reinforcement rate (see de Villiers, 1977, for a review). Alternatively, when responding is maintained by postponement or cancellation of electric shock, preference is usually shown for the alternative providing the greatest relative reduction in shock frequency (Baum, 1973; de Villiers, 1974). In addition, when responding maintained by food presentation also produces electric shock, preference is shown for the alternative providing the lowest relative rate of shock presentation (Deluty, 1976).

In the present experiment, lever pressing by squirrel monkeys was maintained under two FI schedules of electric-shock presentation. The monkeys could choose between the schedules by pressing a second, changeover, lever. The logic of this approach was quite simple: If shock-maintained behavior represents a case in which shock presentation functions as a positive reinforcer under interval schedules, the preferred schedule should be the alternative providing the highest relative rate of shock presentation (the shorter FI); if, on the other hand, shock-maintained behavior represents a special case of aversive control, then the preferred schedule should be the alternative providing the lowest relative rate of shock presentation (the longer FI).

Previous experiments conducted in this laboratory examined squirrel monkeys' lever pressing under standard concurrent schedules of shock presentation in which schedule components were programmed for separate levers (Webbe, 1974). Although responding was maintained under concurrent VI schedules, preference was not systematically correlated with relative shock frequency. Under those conditions, the monkeys often responded simultaneously on the two levers (compatible concurrent operants). This may have precluded an adequate assessment of the relative reinforcing or punishing efficacy of conditions associated with different shock rates by allowing contingencies arranged for one alternative

to directly affect responding in the other (see Catania, 1966). To prevent simultaneous responding on both "main" levers, the present experiment used a related procedure, similar to the one described by Findley (1962). An FI 6-min and an FI 2-min schedule of shock presentation, each associated with different discriminative stimuli, were programmed for responses on a single (main) lever, and subjects could alternate between schedules by responding on a second, retractable, lever (the change-over, or CO, lever).

In a pilot study, monkeys were allowed access to the CO lever following the first shock delivery in a given FI. A single press on the CO lever changed the schedule of shock presentation to the alternate FI. Whenever five consecutive shocks occurred in a given FI, a changeover to the other FI automatically followed delivery of the fifth shock. Under these conditions no preference was obtained, because the monkeys pressed the CO lever following each shock delivery. However, postshock changeover latencies from the FI 6-min schedule were considerably longer than those from the FI 2-min schedule. It appeared from the particular location of CO lever presses that those variables controlling the temporal pattern of responding on the main lever may have simultaneously controlled the temporal placement of CO lever responding. Indeed, when more than one CO lever press was required for a changeover, the changeover ratio was initiated at approximately the same point within the intershock interval as the first response on the main lever. Alternating between presses on the two levers was also observed. It is possible, then, that responding on the main lever and responding on the CO lever were interchangeable members of a single response class.

Numerous experiments report that frequency of food or shock presentation can exert powerful and systematic control over preference (e.g., de Villiers, 1977). The disparity between the results of those studies and those of the pilot study suggests that the variables controlling temporal placement of CO and main lever pressing may have masked or overridden the effects of shock frequency on preference. In an attempt to eliminate or minimize the effects of these variables, the present experiment employed a variation of the procedure used in the pilot study. Separate and independent choice periods, during which neither

FI schedule operated, were programmed following each shock presentation.

METHOD

Subjects

Two adult male squirrel monkeys (*Saimiri sciureus*), SM-37N and SM-43, served as subjects. Both monkeys had previous experience under schedules of electric-shock presentation (SM-37N: Malagodi et al., 1981; SM-43: Malagodi et al., 1978). Each was individually housed in a colony room with food and water continuously available.

Apparatus

A Plexiglas chair, similar to the one described by Hake and Azrin (1963), was enclosed in a ventilated sound-attenuating chamber similar to that described by Weiss (1970). Each monkey was restrained in the seated position by a waist lock, with its tail held motionless by a small stock. Electric shocks (300 V, 60 Hz) of 100-ms duration were delivered by a BRS-Foringer (Model SG-901) constant-current AC shock generator through a series resistance of 50-K ohms to two hinged brass plates that rested on a shaved portion of the tail. Shock intensity was 6 mA for SM-37N and 4 mA for SM-43. Conductivity gel (Lectron II) ensured low resistance between the tail and brass plates. One lever (Lehigh Valley 1352), the shock lever, was mounted on the left side of the front wall, 6.0 cm above the waist plate and 4.0 cm from the left wall. Lever presses with a downward force greater than 0.2 N registered as responses and, unless otherwise noted, briefly operated a feedback relay located within the chamber. A second lever (Lehigh Valley 1405R retractable lever), the changeover (CO) lever, was mounted on the right side of the front wall, 12.0 cm above the waist plate and 4.0 cm from the right wall. When inserted, presses on this lever with a force greater than 0.2 N counted as responses and briefly operated the feedback relay. A 28-V DC white light was located 5 cm above the changeover lever. General illumination was provided by two pairs of 7-W 115-V AC houselights (yellow and blue) located at the top of the front wall. White noise was present in the chamber except when otherwise indi-

cated. All experimental events were programmed and recorded by electromechanical equipment located in an adjoining room.

Procedure

At the end of a pilot experiment, both monkeys were responding under 6-min and 2-min fixed-interval schedules (FI 6 and FI 2) in which a brief electric shock was presented for the first press on the shock lever after either 6 min or 2 min had elapsed since the previous shock. For SM-37N, blue and yellow houselights accompanied the FI 6 and FI 2 schedules, respectively. For SM-43, the stimuli were reversed. Responses on the shock lever continued to produce shock according to an FI 6 or an FI 2 schedule in the presence of their correlated stimuli. Sessions began with one or the other FI in effect (determined randomly). Upon delivery of one shock in a given schedule, the FI contingency was suspended and a choice period was initiated. During the choice period, the FI correlated stimulus remained illuminated, the CO lever was inserted, and the white light was illuminated. A single CO lever press (FR 1) produced the alternate schedule and its correlated stimulus. Following a changeover, the CO lever was retracted and the white light was turned off. If no CO lever press occurred during the choice period, the CO lever was retracted, the white light turned off, and the most recent FI schedule was reinstated. Note that the stimulus correlated with the most recent FI was on during the choice period, so it simply remained on if no changeover occurred.

Choice periods followed the first through fourth shocks in a given schedule. If no CO lever press occurred during each of these choice periods, a changeover to the other FI automatically followed delivery of the fifth shock. Thus, in a given exposure to either FI, the opportunity to change over was available after one shock presentation, and a maximum of five consecutive shocks could be received.

Four-minute timeouts preceded and followed all sessions. During timeouts, the chamber was dark, white noise was absent, a clicking sound was present, and lever presses had no programmed consequences. Sessions terminated after delivery of the 30th shock. Thus, the maximum number of shocks per session that could be received in any schedule was 25, and the minimum was five. Sessions usually were conducted 5 days per week. The effects of various choice-period features were examined in separate phases.

Phase I: fixed choice periods. For both monkeys, the choice-period durations were 1 min during the first session. The durations were then decreased by 10 s for each of the next five sessions, reaching a minimum value of 10 s. Because of a complete absence of CO lever pressing during two sessions at 10 s, the choice-period duration for SM-43 was increased to 30 s.

Phase II: proportional choice periods. After 78 (SM-37N) and 76 (SM-43) sessions under Phase I, the choice periods were changed such that their durations were proportional to the FI values. For SM-43, the choice periods were 30 s following shock presentations in FI 2 and 90 s following shock presentations in FI 6. These values for SM-37N were 60 s and 180 s, respectively. The durations selected were longer than the average changeover latencies obtained during the aforementioned pilot study. After 28 sessions, these values for SM-37N were increased to 120 s (FI 2) and 360 s (FI 6) for 20 sessions.

Following 50 sessions under this proportional choice-period arrangement, SM-43 was returned to the 30-s fixed choice period of Phase I for 31 sessions, and was then reexposed to Phase II conditions for 51 sessions.

Phase III: reversal of changeover contingencies. Following the second exposure to Phase II conditions, the contingencies for pressing the CO lever were reversed for SM-43 such that during the choice periods, a press on the CO lever retracted the lever, turned off the white light, and reinstated the most recent FI schedule. If no CO lever press occurred during the choice period, the lever was retracted, the white light was turned off, and the schedule was changed to the alternate FI. Thus, in Phase III a CO lever response constituted a choice for the most recent FI, and the absence of such a response constituted a choice for the alternate FI. If a CO lever press occurred following each of the first four shocks (i.e., the subject remained in a given FI), the schedule was automatically changed to the other FI after delivery of the fifth shock. Choice-period durations remained at 30 s (FI 2) and 90 s (FI 6), and all other conditions were the same as in the previous phase. SM-43 was exposed to these conditions for 55 sessions. SM-37N became ill after completing Phase II and was not exposed to the conditions of Phase III.

Table 1

Median response rates, pause durations, shock rates, and postshock CO latencies for both monkeys from the last 11 sessions under all conditions. Numbers in parentheses are ranges.

	Responses/min	Pause/shock (min)	Shocks/hr	CO latency (s)
SM-37N				
Phase I: fixed 10-s choice period				
FI 6 min	17.0 (13.9–20.0)	1.9 (1.4–2.6)	9.9 (9.6–10.0)	7 (4–9)[a]
FI 2 min	24.0 (15.8–29.8)	0.7 (0.4–0.9)	29.4 (29.0–30.0)	6 (2–9)
Overall			11.8 (10.5–12.0)	
Phase II: proportional 60/180-s choice period				
FI 6 min	23.2 (16.6–28.0)	1.6 (1.0–2.0)	7.7 (7.2–8.3)	138 (96–171)[a]
FI 2 min	26.1 (18.6–34.4)	0.7 (0.3–0.8)	29.8 (28.6–30.0)	15 (8–32)
Overall			9.3 (8.9–10.5)	
Phase II: proportional 120/360-s choice period				
FI 6 min	21.6 (13.4–24.0)	1.4 (0.9–1.7)	6.2 (5.9–6.8)	156 (112–236)[a]
FI 2 min	27.8 (20.1–31.2)	0.8 (0.3–1.0)	26.6 (25.0–27.7)	24 (18–52)
Overall			7.7 (6.9–8.2)	
SM-43				
Phase I: fixed 30-s choice period				
FI 6 min	39.8 (35.6–48.0)	1.0 (0.7–1.2)	9.4 (9.4–9.7)	24 (15–28)[a]
FI 2 min	42.3 (38.1–58.3)	0.8 (0.6–1.0)	29.3 (28.9–29.5)	17 (9–23)
Overall			11.1 (10.8–12.3)	
Phase II: proportional 30/90-s choice period				
FI 6 min	36.5 (27.9–47.1)	1.0 (0.6–1.2)	9.0 (8.6–9.3)	38 (22–61)
FI 2 min	37.9 (29.5–51.3)	0.5 (0.4–0.9)	26.3 (25.9–26.5)	24 (16–28)
Overall			13.6 (12.5–13.9)	
Phase I (2nd exposure): fixed 30-s choice period				
FI 6 min	38.6 (33.8–42.2)	0.8 (0.5–1.0)	9.4 (9.3–9.4)	20 (12–24)[a]
FI 2 min	40.0 (30.1–48.6)	0.5 (0.3–0.6)	26.5 (25.8–27.1)	14 (6–21)
Overall			10.8 (10.4–11.5)	
Phase II (2nd exposure): proportional 30/90-s choice period				
FI 6 min	33.6 (24.4–36.7)	1.1 (0.5–1.4)	9.0 (8.6–9.2)	34 (23–49)[a]
FI 2 min	35.8 (22.8–38.3)	0.8 (0.5–1.0)	26.5 (25.3–27.0)	21 (11–25)
Overall			10.3 (10.0–10.8)	
Phase III: 30/90-s choice period, reversed CO contingencies				
FI 6 min	32.5 (30.2–39.1)	0.7 (0.4–0.8)	9.7 (9.3–10.2)	30 (18–50)
FI 2 min	30.8 (24.8–33.2)	0.4 (0.3–0.6)	23.6 (22.3–25.1)	12 (9–21)[a]
Overall			10.8 (10.1–13.3)	

[a] The number of values used to calculate these medians is reduced due to relatively fewer changeovers following shock presentations under these schedules.

RESULTS

For both monkeys, responding on the shock lever in both FI schedules consisted of a pause at the beginning of the interval followed by either a steady or a positively accelerated rate of responding until shock presentation. In general, response rates were higher and pause times were shorter in the FI 2 schedule. These data are shown in Table 1, as are rates of shock presentation in the presence of each FI-correlated stimulus and overall shock rates. Results for measures of preference will be described separately for each monkey.

SM-37N. Performance of this monkey in all phases is illustrated by the cumulative record in Figure 1 and by graphs of the average number of shocks per changeover and the number of shocks per session under each schedule in Figure 2. The record in Figure 1 and the left panels of Figure 2 show that under the fixed choice period condition (Phase I), this monkey nearly always changed from FI 2 after a single shock and tended to remain in FI 6 for multiple shocks, often to the maximum. This resulted in many more shocks per session in FI 6 than in FI 2. Figure 1 also shows that although many more shocks were received in FI 6, this
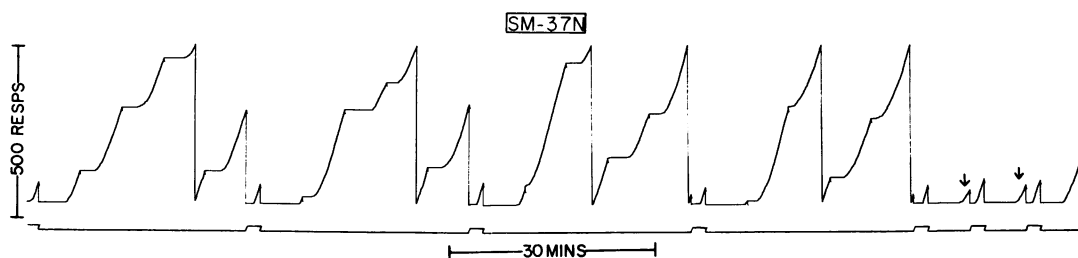
Fig. 1. A cumulative record of responding for SM-37N from Phase II. This performance is representative of that observed throughout all phases. The response pen stepped with each response on the shock lever, deflected when shock was delivered, and reset when changeovers occurred (or at the top of the page). The event pen was displaced during the FI 6-min schedule. The recorder motor did not operate during the choice periods. Arrows point to instances in which a changeover occurred following a single shock presentation under the FI 6-min schedule.

monkey occasionally changed from FI 6 before the maximum (shown by the arrows).

Preference was affected very little by changing from fixed to proportional choice periods (the middle panels of Figure 2), or by elongating the proportional choice periods (the right panels of Figure 2). Under all conditions, SM-37N consistently changed from FI 2 after one shock and averaged three or four shocks per changeover from FI 6. This resulted in over 20 shocks per session in FI 6 and fewer than 10 shocks per session in FI 2. Note that, for this monkey, whenever a changeover from FI 6 occurred prior to the delivery of the maximum number of shocks, it usually occurred after one (sometimes two) shock presentation (see Figure 1). Rarely did a changeover from FI 6 occur after an intermediate number of shocks, especially under the proportional choice-period procedure.

As seen during the pilot study, changeover latencies for SM-37N were always longer in FI 6 (when they occurred) than in FI 2 (see Table 1).

SM-43. Figures 3, 4, and 5 summarize performance of SM-43 under all phases of the experiment. For this monkey, the changeover pattern under the fixed choice-period condition of Phase I was similar to that seen with SM-37N, showing a distinct preference for FI 6. This is illustrated in Panel A of Figures 3 and 4. For the last 11 sessions of Phase I, this monkey usually averaged over four shocks per changeover in FI 6 and fewer than 2 shocks per changeover in FI 2. This resulted in more than 20 shocks per session in FI 6 and fewer than 10 shocks per session in FI 2. Panel B of Figure 4 presents these data for the first

and last 11 sessions of the initial exposure to the proportional choice-period condition of Phase II. In this phase, a pattern of changing after a single shock in each component occurred immediately in the first session. In the following three sessions, a few extra shocks were received in the FI 2 schedule until, by the seventh session, a stable pattern of changing after each shock appeared and persisted for the remainder of this phase (Figure 3B).

The return to fixed choice periods immediately produced a changeover pattern similar to that seen in the previous exposure to these contingencies. Again, many more shocks per changeover and per session were received in FI 6 (Panel C of Figure 4). This pattern continued for the remaining sessions of this phase.

Panel D of Figure 4 shows changeover performance for all sessions under the second exposure to the proportional choice-period procedure. This phase was characterized by an immediate return to changing after each shock in both schedules. This pattern persisted for about 15 sessions and was then followed by a transition to one of changing after a single shock in FI 2 and remaining in FI 6 for multiple shocks, often to the maximum.

Figure 5 shows daily plots of preference data for the first and last 11 sessions for SM-43 when the contingencies for CO lever responses were reversed (Phase III). Changeover lever pressing in this monkey was affected in the first session under these contingencies. The initial effect was a reduction in CO lever pressing during the choice periods that followed FI 2 shocks, resulting in changeovers to FI 6. During the third and fourth sessions, lever presses began to occur during the choice pe-

riods that followed FI 6 shocks, reinstating this schedule. Over the next several sessions under these conditions, a distinct preference for FI 6 developed and persisted throughout this phase. That is, a CO lever press followed most shock deliveries in FI 6 and failed to follow most shock deliveries in FI 2. Postshock changeover latencies for SM-43 under all conditions are shown in Table 1. Note that, as with SM-37N, the average latency was longer in FI 6 than in FI 2.

DISCUSSION

Throughout this experiment, lever pressing was maintained under 6-min and 2-min FI schedules of electric-shock presentation. When separate and independent choice periods followed each shock presentation and when the durations of those choice periods were fixed, both monkeys tended to change from FI 2 after a single shock and remain in FI 6 for multiple shocks. When the choice-period durations were changed to equal a value proportional to the prevailing FI parameter, both monkeys received many more shocks in FI 6 than in FI 2. SM-37N did so upon the initial exposure to these conditions, and SM-43 did so following an intervening exposure to the fixed choice-period condition. SM-43 continued to show a preference for FI 6 when contingencies for CO lever pressing were reversed such that responses reinstated the most recent FI.

The results for SM-37N indicate that, by arranging separate and independent choice periods, the apparent control of CO lever pressing by the temporal factors that occurred during the pilot study was minimized. The continued preference for FI 6 under the proportional choice-period condition implies that the preference for FI 6 obtained under the fixed choice-period condition was not artificially created by removing the CO lever during periods in which a press after an FI 6 shock was most likely. It appears, then, that CO lever pressing in this monkey was controlled by consequent presentation of stimuli correlated with different shock rates.

The data for SM-43 during Phase I and the initial exposure to Phase II conditions suggest the possibility of control by the temporal factors discussed earlier. Note the immediate transition to changing after each shock upon initial introduction of Phase II and the im-
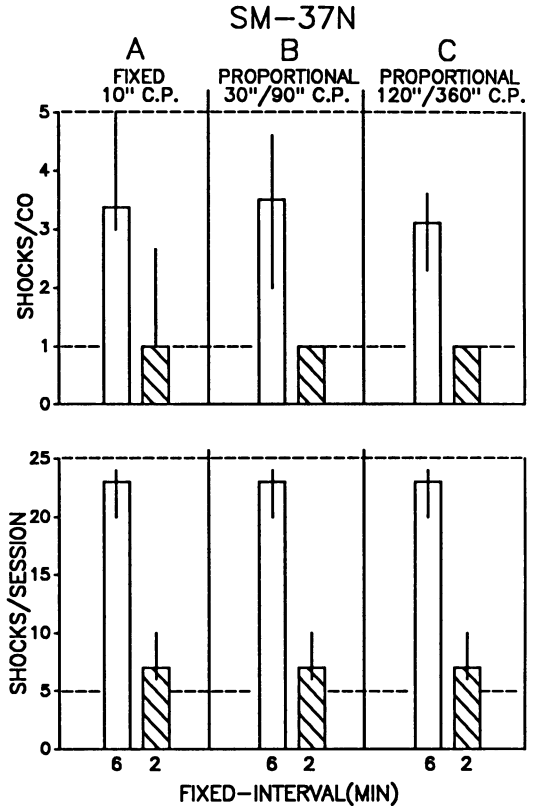

Fig. 2. Medians and ranges of the average number of shocks received per changeover and the number of shocks received per session by SM-37N during the FI 6-min (open bars) and the FI 2-min (striped bars) schedules during all phases. Dashed lines indicate the minimum and maximum number of shocks that could be received. Data in Panel A are from the fixed choice-period condition of Phase I, and data in Panels B and C are from the proportional choice-period conditions of Phase II. All values are from the last 11 sessions. C.P. = choice period.

mediate return to changing only after FI 2 shocks upon reintroduction of Phase I. It is possible that during Phase I, an artificial preference for FI 6 was created by removing the CO lever prior to the time that a changeover was likely to occur. (Note that, throughout Phase II, the average latency from FI 6 for this monkey was longer than the 30-s choice period used in Phase I.) The data from the second exposure to Phase II, however, indicate that, by midway through this phase, the control by temporal variables was attenuated, and a preference based on the consequent control of stimuli associated with shock rate had developed. The reasons for this are not clear. However, other studies of shock-maintained
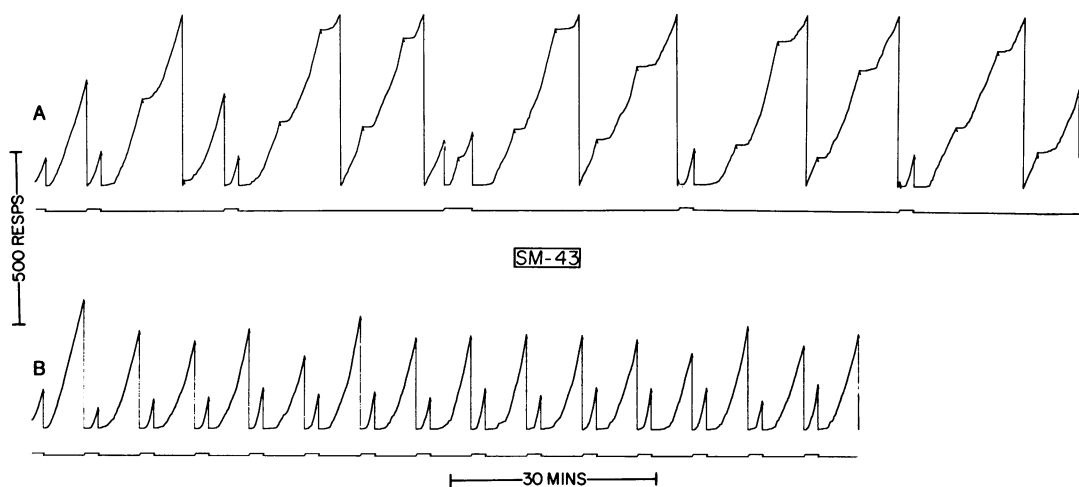
Fig. 3. Cumulative records for SM-43 from the first exposure to the fixed choice-period condition of Phase I (Record A), and from the first exposure to the proportional choice-period condition of Phase II (Record B). Responding shown in Record A was similar to that seen under all conditions in which a preference was shown for FI 6. Responding shown in Record B was indicative of that seen under all conditions in which no preference was obtained. Recording, display, and selection conventions are the same as in Figure 1.

behavior have reported relatively abrupt changes in responding following over 60 sessions of stable performance (Branch & Dworkin, 1981). It may have been that the final performance seen during the second exposure to Phase II would have developed with a more prolonged exposure the first time.

Certain features of CO lever pressing, however, suggest the possibility of control by sources other than the contingent presentation of stimuli correlated with shock rate. That both monkeys occasionally changed from FI 6 prior to the maximum number of shock deliveries, and that this often occurred following a single shock, implies that some of the CO lever presses may have been elicited or induced by shock presentation.

The results with SM-43 in Phase III, during which responses on the CO lever reinstated the most recent FI, are especially important. Although logically possible, it is unlikely that the data obtained in earlier phases resulted from differential induction or elicitation by the different FI schedules. If, for example, the preference for FI 6 resulted from elicitation of CO lever pressing by the higher rate of shock presentation in the FI 2 schedule, it seems likely that a similar pattern of CO lever pressing would have been observed in Phase III. This would have resulted in a preference for

the FI 2 schedule. The rapid transition from pressing the CO lever after FI 2 to pressing after FI 6 suggests that this was not the case.

The data from the present experiment are similar to those from other experiments showing that shock presentation can suppress and maintain responding in the same experimental session (Barrett & Glowa, 1977; Kelleher & Morse, 1968; McKearney, 1972) and to those showing that both the presentation and termination of electric shock can maintain responding within the same session (Barrett & Spealman, 1978). In addition, responding can be maintained by termination of a schedule of self-administered cocaine (Spealman, 1979), and lever pressing by food-deprived rats can be maintained under conditions in which responses postpone food presentation (Clark & Smith, 1977; Smith & Clark, 1972). Together, these data imply that the behavioral functions of a number of consequent stimuli may not be inherent and immutable, but may depend critically on the experimental context in which they are presented. The results of these and similar studies are often cited in support of the "schedules as fundamental determinants of behavior" conceptualization outlined earlier. An interpretation of the present results in terms of this view suggests that FI presentation of shock positively reinforced shock lever press-
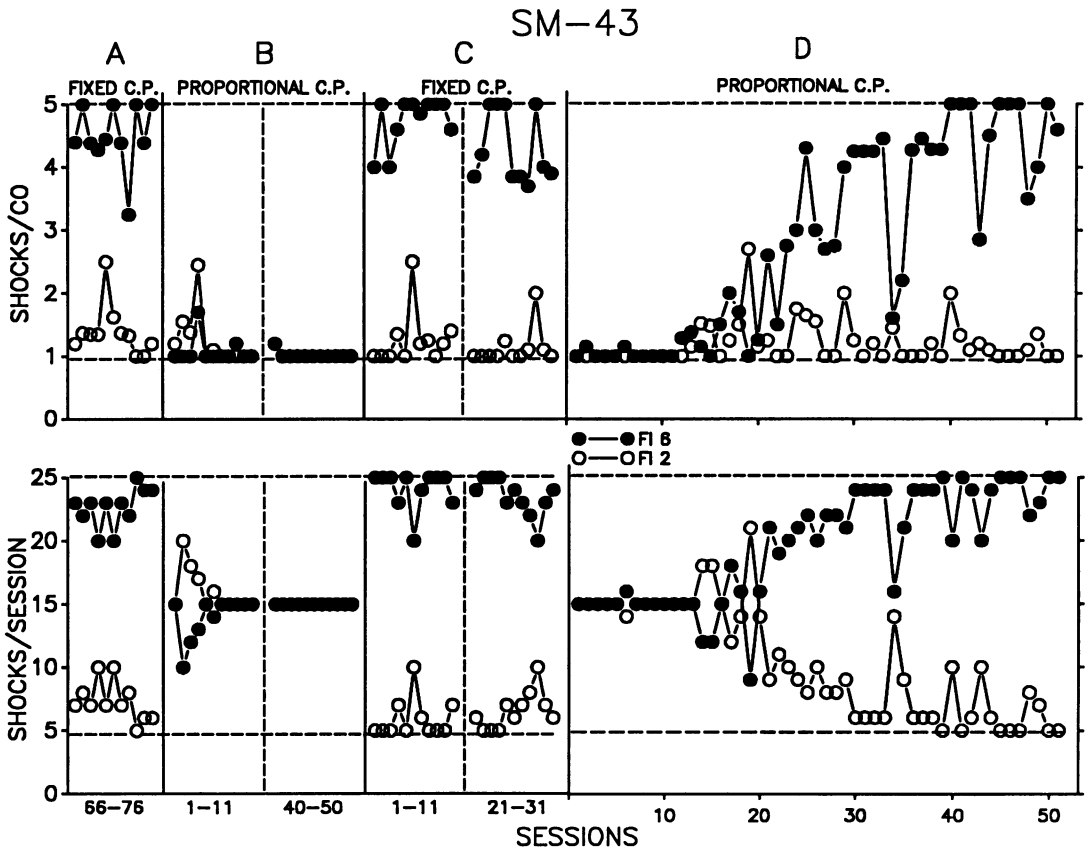
Fig. 4. Daily plots of the average shocks per changeover and number of shocks per session from the FI 6-min (closed circles) and the FI 2-min (open circles) schedules for SM-43 during various portions of the experiment. In Panel A, data points are from the last 11 sessions of the initial exposure to the fixed choice-period condition (Phase I). In Panel B, data points are from the first and last 11 sessions of the initial exposure to the proportional choice-period condition (Phase II). In Panel C, data points are from the first and last 11 sessions of the second exposure to Phase I conditions. In Panel D, data points are from all sessions of the second exposure to Phase II conditions. Solid vertical lines divide data from the different choice-period conditions, and dashed vertical lines divide data from the first and last 11 sessions of a given condition. Other display conventions are the same as in Figure 2.

ing, but that fixed-ratio presentation of schedule-correlated stimuli exerted aversive control over CO lever pressing.

However, an interpretation of the present data entirely within the context of the above view seems problematic. First, no present framework exists, based on this formulation, that would permit specific predictions as to whether or not a particular arrangement of stimulus presentation will maintain or suppress responding. The quantitative dimensions upon which such a prediction would be based remain to be identified. Second, such an interpretation seems to require a restructuring of current theorizing regarding the nature of reinforcement. Given the observed preference

for less frequent shock, to conclude that the maintenance of responding on the shock lever resulted from positive reinforcement would necessarily require a dissociation of notions of reinforcement value and preference as currently used (e.g., Rachlin, 1978). At present, such a dissociation seems unwarranted.

The data presented here are consistent with those of previous experiments on choice and negative reinforcement (Baum, 1973; de Villiers, 1974; Logue & de Villiers, 1978). In each of these studies, subjects allocated responses to an alternative that provided a reduction in the frequency of electric shock. The changeover pattern generally observed in the present experiment suggests that shock presentation may
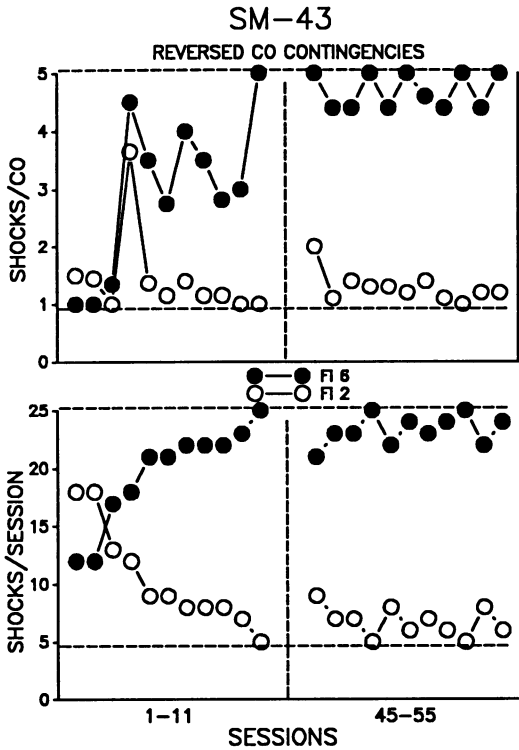
SM-43

REVERSED CO CONTINGENCIES

Fig. 5. Daily plots of the average number of shocks per changeover and number of shocks per session in each schedule for SM-43 during the first and last 11 sessions of Phase III (when changeover contingencies were reversed). Display conventions are the same as in Figure 4.

have functioned as an aversive stimulus in much the same manner as in those experiments. Thus, CO lever presses that followed shocks on the FI 2 schedule in Phases I and II and shocks on the FI 6 schedule in Phase III may have been negatively reinforced by the presentation of stimuli correlated with a relatively lower shock rate and/or longer delay to shock. Conversely, CO lever presses that followed shocks on the FI 6 schedule in Phases I and II and shocks on the FI 2 schedule in Phase III may have been punished by the presentation of stimuli correlated with a relatively higher shock rate and/or shorter delay to shock. If such were the case, it seems quite possible that shock lever pressing also resulted from processes involving aversive control, rather than from those involving positive reinforcement.

The results presented here provide support for views suggesting that shock-maintained behavior results from aversive control. Demonstrations that response-independent presen-

tations of shock can produce a number of responses (including lever pressing) have led some investigators to suggest such responding is elicited or induced as a by-product of aversive control, of which shock-maintained behavior may be an example (Hutchinson, 1977; Hutchinson et al., 1971). Another view of shock-maintained behavior also suggests that shock consistently functions as an aversive stimulus, but that maintenance of responding by shock presentation under interval schedules occurs because relatively long IRTs are selectively punished (Galbicka & Platt, 1984). In this view, the schedule under which shock is presented changes not the stimulus function of shock but rather the behavioral unit upon which shock operates. Support for this view derives from observations that (a) shock-maintained behavior is readily maintained under interval schedules, which possess the property that relatively long IRTs differentially receive consequences, but is not usually maintained under ratio schedules, which do not possess this quality (e.g., Branch & Dworkin, 1981; McKearney, 1972; but see Howell, Byrd, & Marr, 1983), (b) presentation of shock contingent upon relatively long IRTs can result in an increase in the rate of responding conjointly maintained by food presentation (Galbicka & Branch, 1981) or shock avoidance (Galbicka & Platt, 1984), (c) responding is not maintained by shock presentation alone when shock is delivered independently of the current IRT (Galbicka & Platt, 1984), and (d) apparent differences in drug effects on behavior maintained or punished by response-produced shock are reconciled within the context of an IRT-punishment view (Galbicka, 1990). It may have been that lever responding maintained by shock in the present experiment was largely controlled by the differential IRT-punishment relation arranged by the interval schedules, and CO lever pressing (under a ratio schedule) was aversively controlled as discussed above.

Although views that shock-maintained behavior results from aversive control are supported by the data presented here, determination of the adequacy and the generality of any particular theory of shock-maintained behavior based upon aversive control must await further analyses. As Galbicka and Platt (1984) point out, it appears that shock-maintained behavior is multiply determined. Thus, it is

unlikely that a complete account of this behavior will emerge from any single available theoretical position. For example, the notion that shock-maintained behavior results from induction/elicitation is compromised by differences between responding maintained under response-dependent and response-independent schedules of shock presentation. Response rates are higher under FI than under equally valued fixed-time (FT) schedules (McKearney, 1974; Malagodi et al., 1978). Further, some experiments report that responding occasionally fails to occur between shocks under FT schedules but virtually always occurs within intervals under FI schedules (Malagodi et al., 1978, 1981). Therefore, although induction/elicitation may contribute, it appears that additional processes are involved in shock-maintained behavior. Also, although IRT-punishment clearly seems important, Galbicka and Platt (1984) note that differential punishment of longer IRTs appears to be a "necessary, but not sufficient, condition for predicting whether consequent shock will maintain or suppress responding" (p. 300). In that study, presentation of shock contingent upon long IRTs failed to regenerate responding that had been completely suppressed under previous conditions. Indeed, it does not seem that punishment of one class of responses (e.g., long IRTs) necessarily implies that another, unpunished, class (e.g., short IRTs) will be maintained in the absence of other supporting contingencies.

Howell et al. (1983) report data that further complicate the picture. In that study, squirrel monkeys responded under a multiple random-interval variable-ratio schedule of shock presentation. Responding was maintained in both components for more than 80 sessions, but only when the number of required responses in the ratio components were yoked to the number of responses emitted during immediately preceding interval components. Thus, although there were some apparent schedule interactions, responding during the ratio component was maintained in the absence of any direct IRT contingencies. Again, it seems that other contingencies were involved.

The present experiment provides support for views that shock-maintained behavior is aversively controlled. However, it seems that there are a number of other sources of control over this phenomenon. Indeed, still other ques-

tions remain, such as a relative lack of species generality and the exact role of induction or elicitation (see Galbicka & Platt, 1984, for a discussion of these issues). The present data suggest, however, that multioperant procedures may possess advantages over single-operant procedures for investigating the stimulus functions of consequent events. Further experiments of this sort may provide a more complete set of principles regarding whether certain arrangements of electric shock, or other consequent stimuli, will maintain or suppress responding.

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